

## Rencontre Jeunes Physiciens (RJP)

# Hypoxia driven micro-phase separation of *social amoebas*

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*Supervised by Jean-Paul RIEU & Olivier COCHET-ESCARTIN*

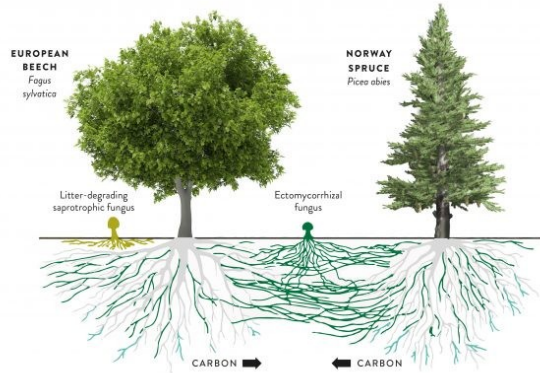
# How to move a 2 ton boat ?



*Physical: 100*



# Cooperativity in nature



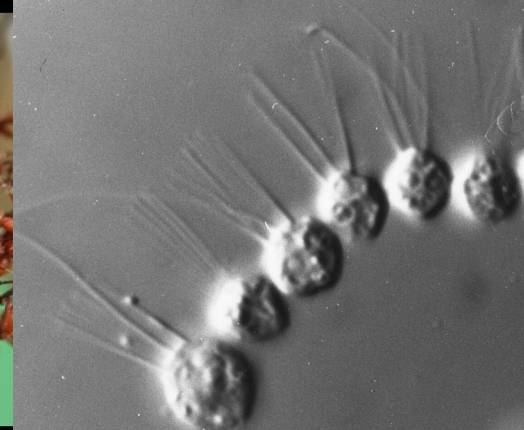
*Mycorrhizal network*



*Fish schooling*



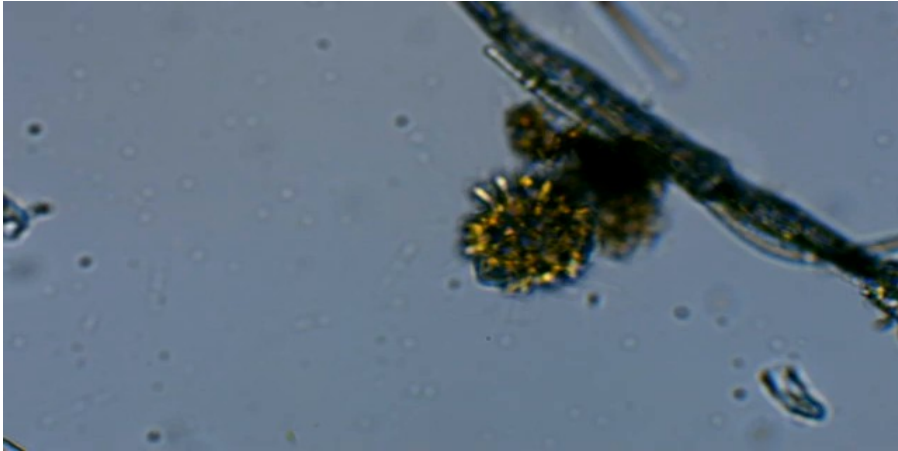
*Ant bridges*



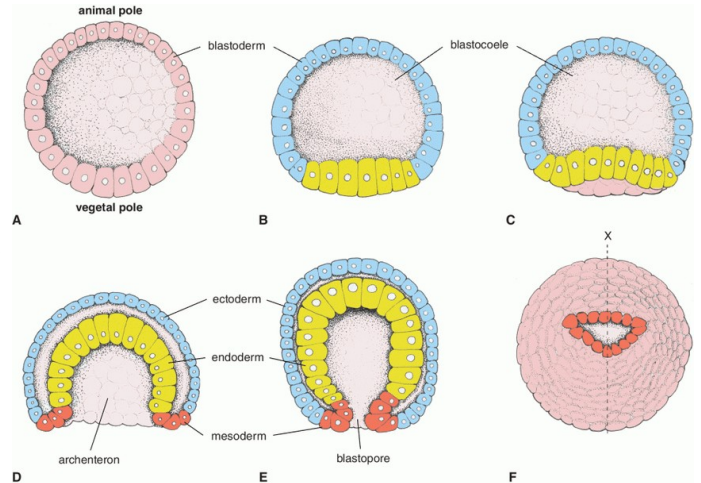
*Choanoflagellata*

**From large to small scale**

# Choanoflagellata: closest cousin to animals

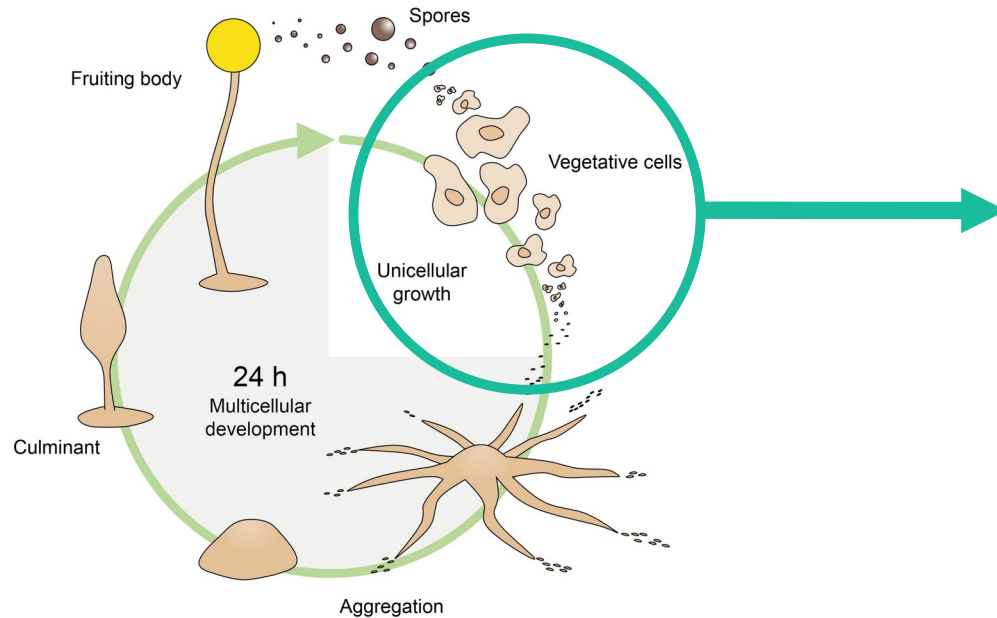


*Colonial Choanoflagellate (in swamp water)*

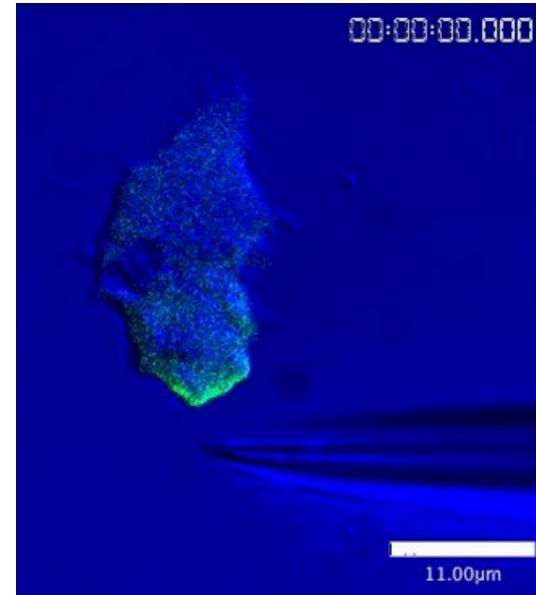


*Gastrulation*

# A model organism



*Dictyostelium* life cycle



*Dicty* cell moving around (membrane protrusion) and following a chemical product (chemotaxis)

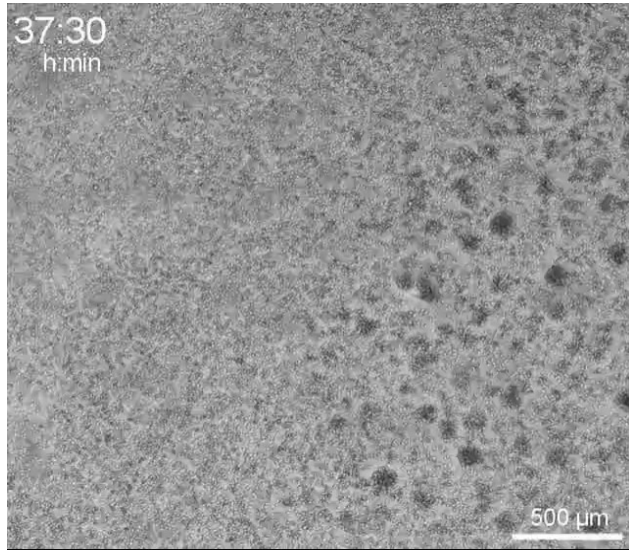
# Dicty together strong (when stressed)



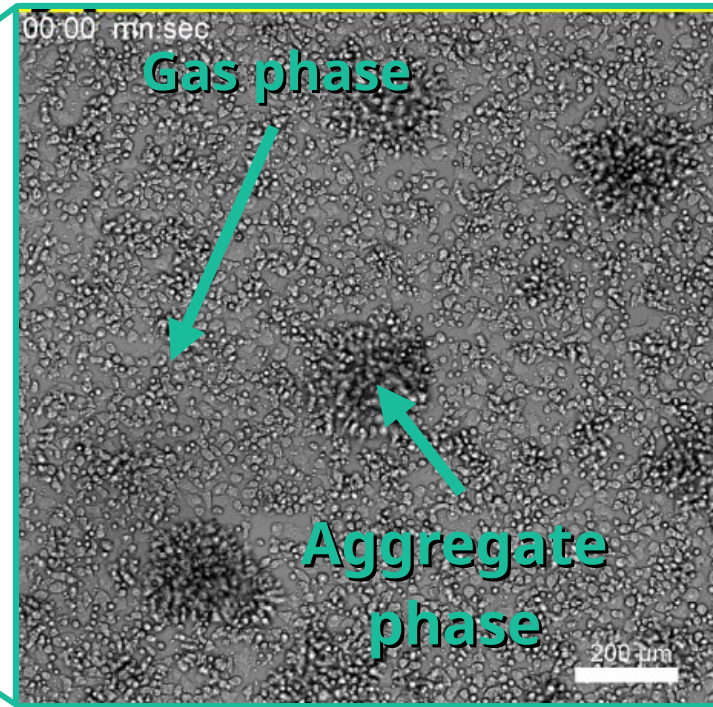
*Dicty aggregation when food is missing*



# Hypoxia induces microphase separation

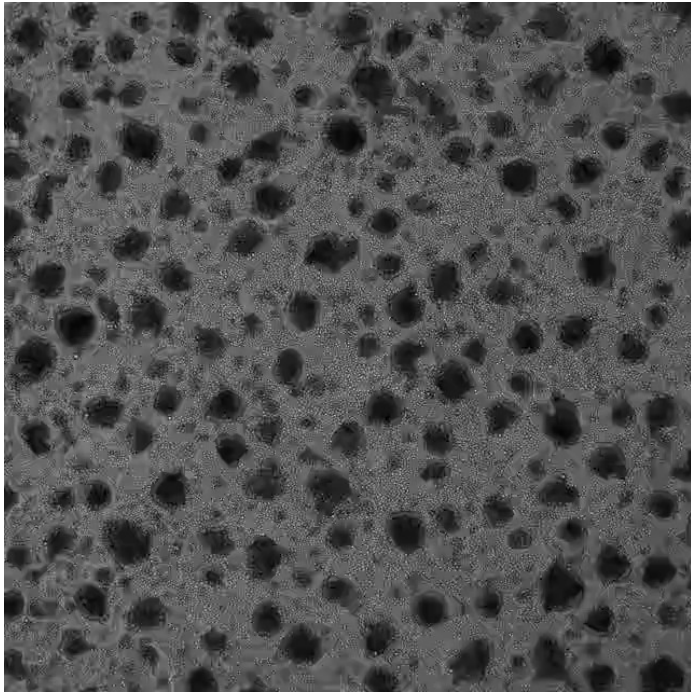


*Brightfield observations of hypoxia triggered microphase separation*



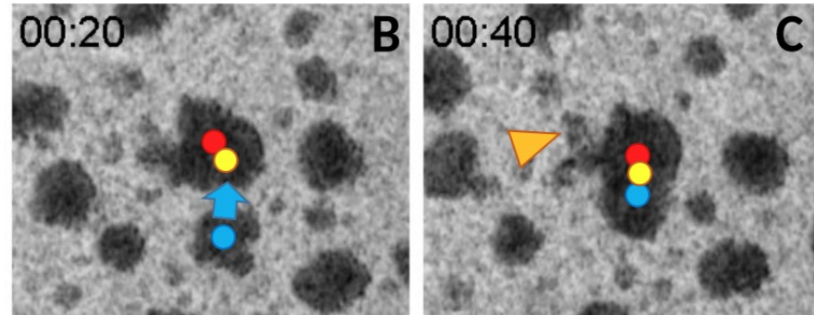
**Stable for days and very dynamic aggregates**

# Hypoxia induces microphase separation

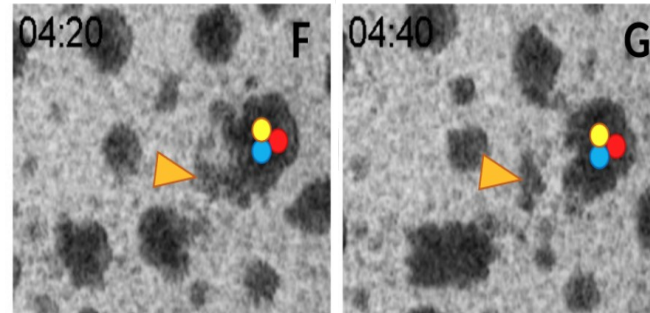


## Highly dynamic

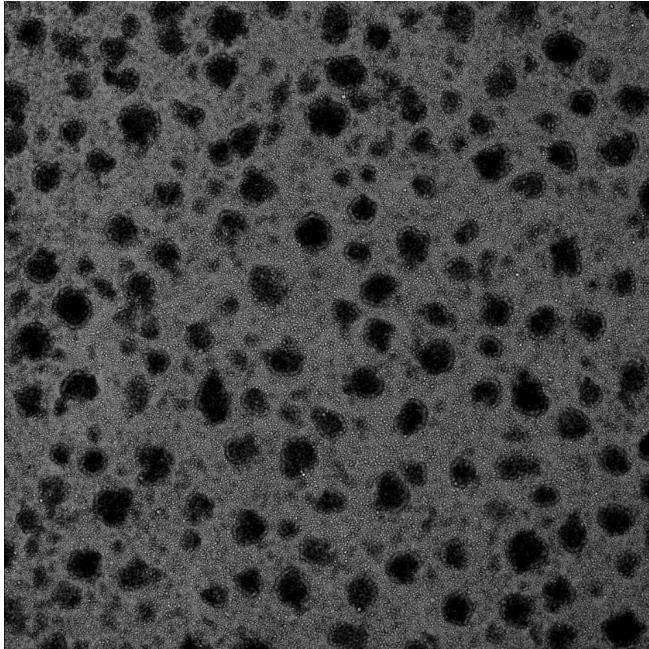
Fusions of aggregates



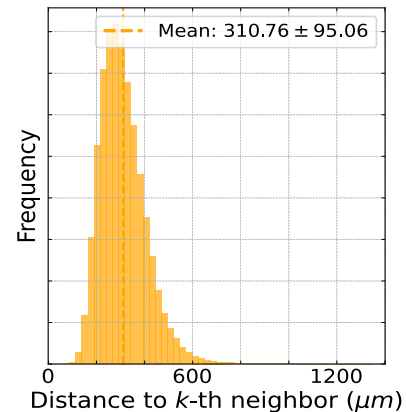
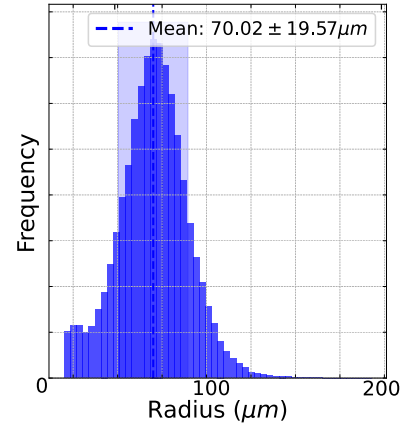
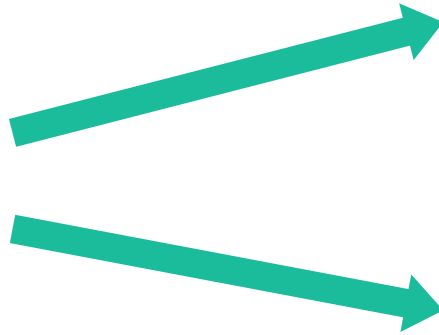
Big aggregates looses "puffs of cells"



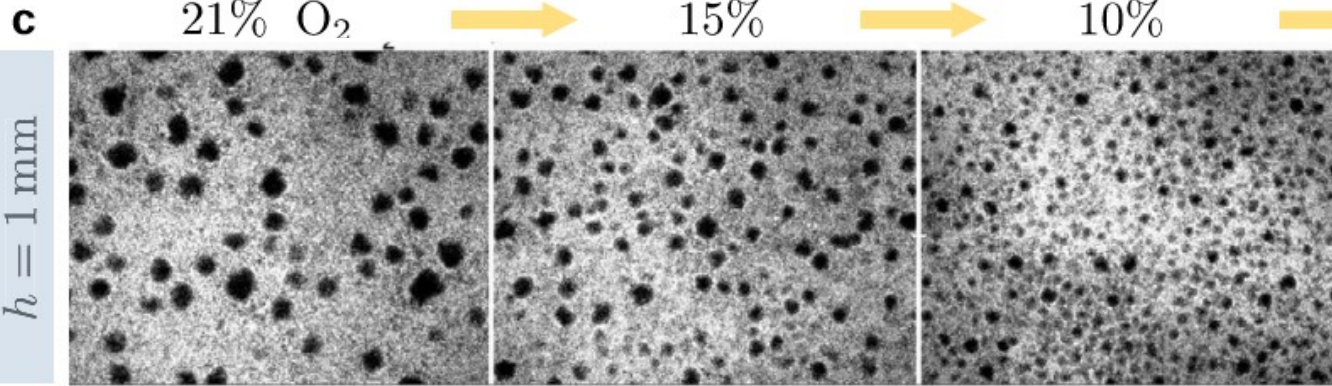
# Hypoxia induces microphase separation



*Brightfield observations of hypoxia triggered microphase separation*

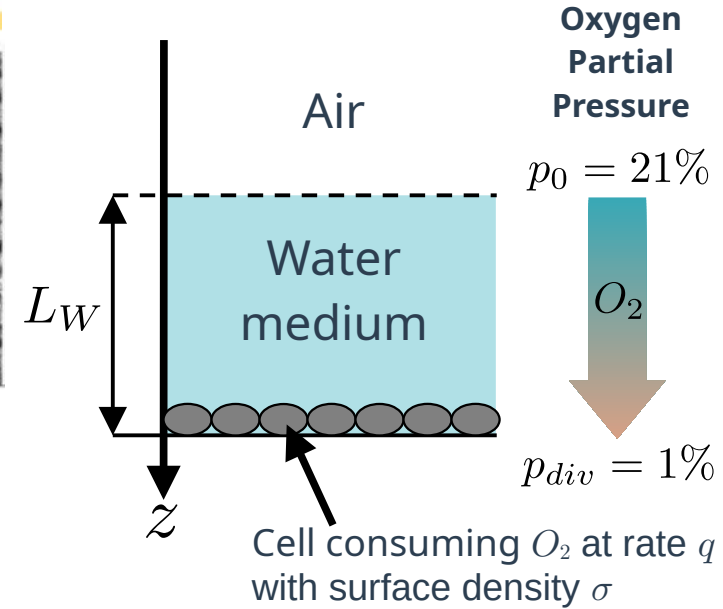


# Oxygen controls aggregate sizes

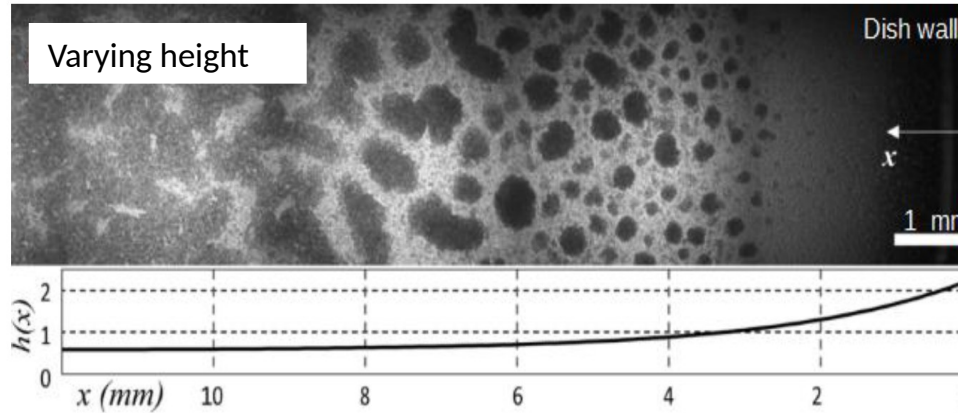


*Effect of a step change in the oxygen content of atmosphere while keeping  $h$  fixed  
(A. Carrère, Nature Communication, 2023)*

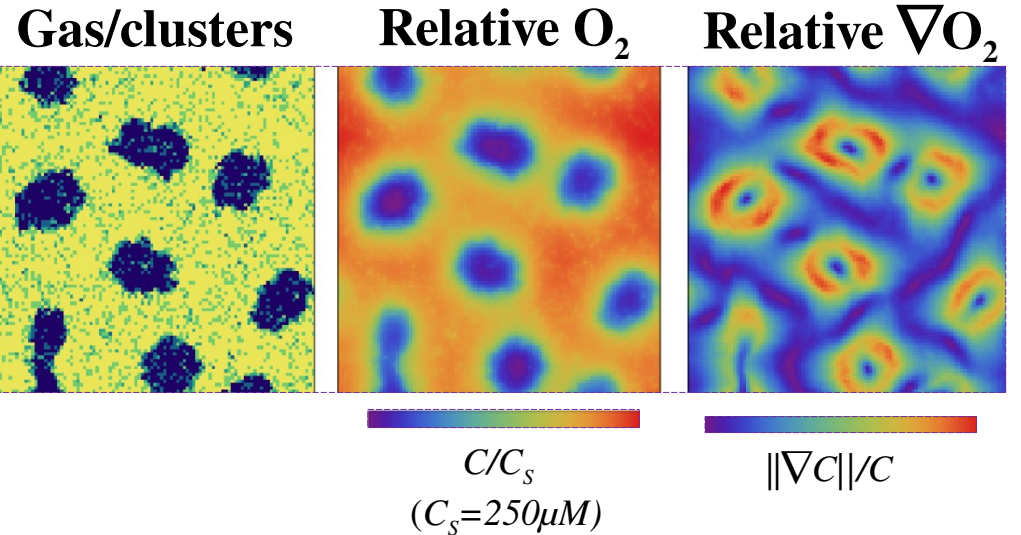
$$\sigma_{\max} = \frac{p_0 - p_{div}}{qR_w} \quad \text{with} \quad R_w = \frac{L_w}{D_w H_w}$$



# Aerotactic model: balance adhesion/repulsion

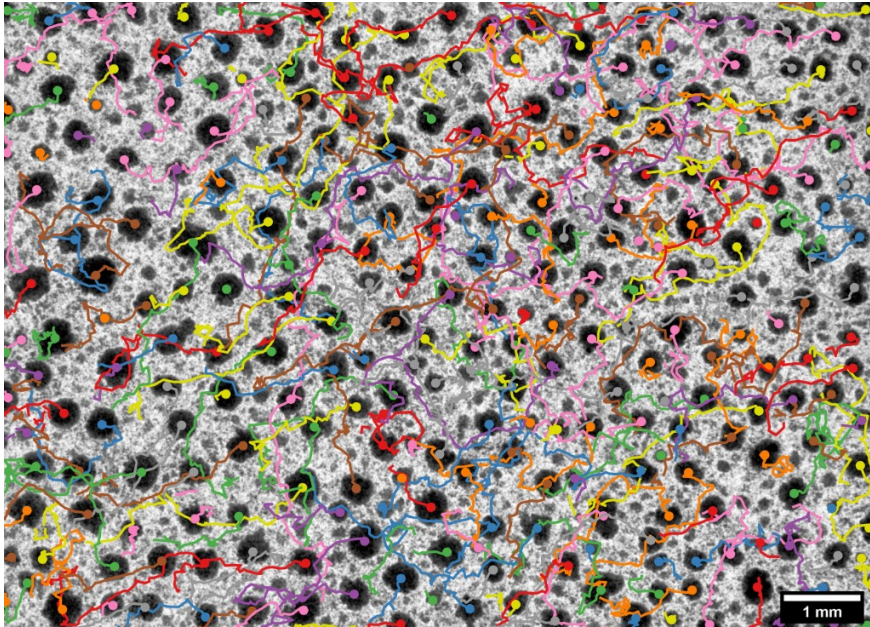


**Meniscus formed by the dish walls make a natural varying height**

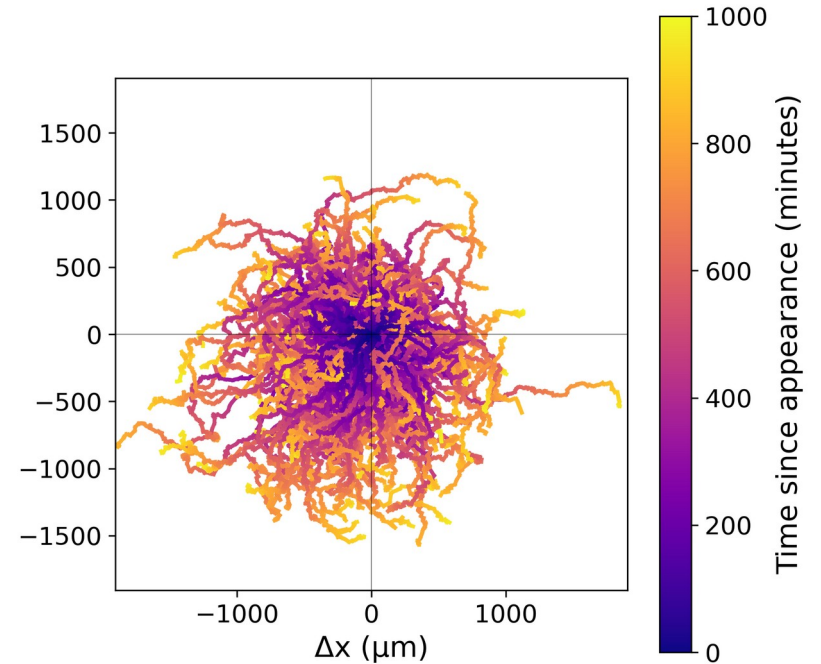


**Aerotactic model developed by A. Carrere and F. Detscherry**  
(A. Carrère, *Nature Communication*, 2023)

# Possibility to track the aggregates



***Trajectories of aggregates tracked over 24h***  
(A. Carrère thesis, 2024)

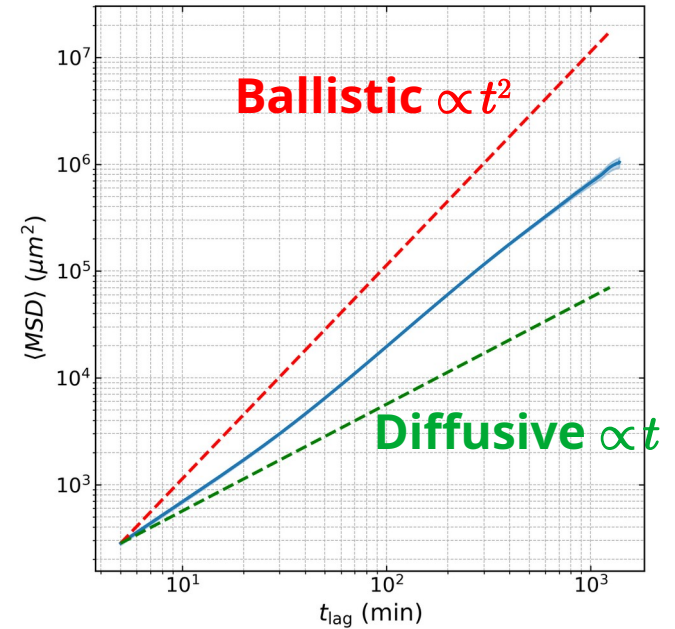
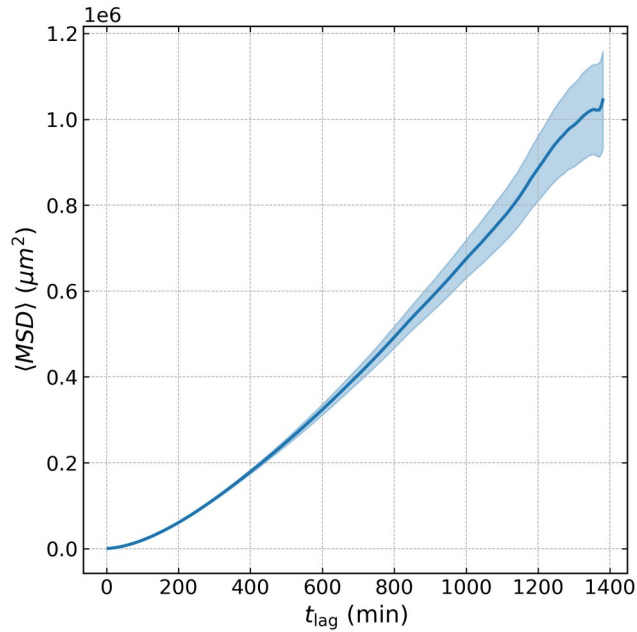
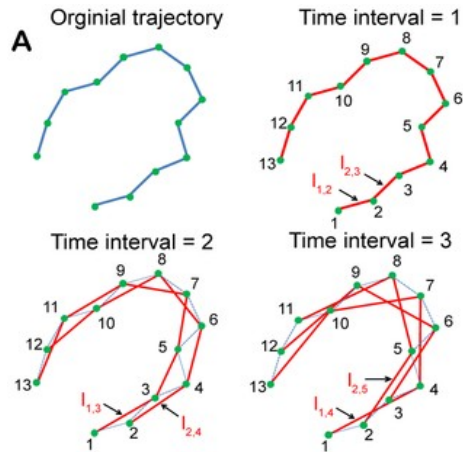


***Centered trajectories of each aggregate***

# Mean square displacement

## Average MSD

$$\text{MSD} = \left\langle |\vec{r}(t) - \vec{r}_0|^2 \right\rangle$$



# Modified Furth function

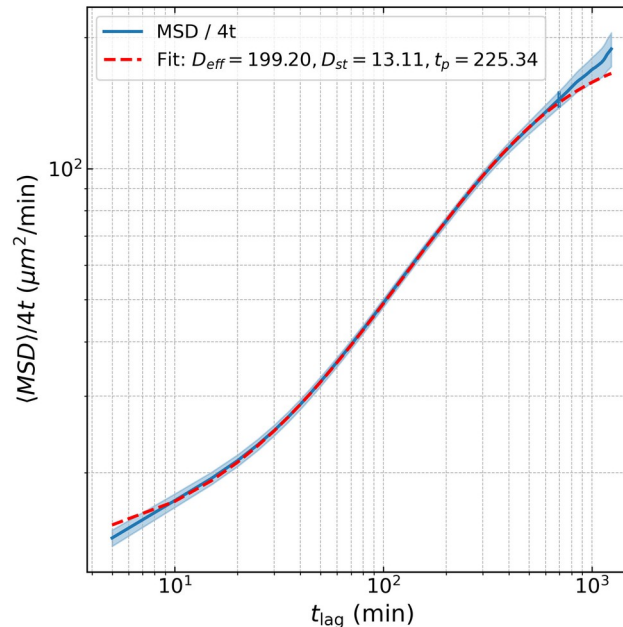
$$MSD(t) = 4(D_{eff} - D_{st}) \cdot \left( t - t_p \left( 1 - e^{-\frac{t}{t_p}} \right) \right) + 4D_{st}t$$

## Brownian persistent :

- For  $\Delta t \gg t_p$ , we get  $MSD(t) \approx 4D_{eff}t$
- For  $\Delta t \approx t_p$ , we have an intermediate “ballistic”-like regime

## But with another regime :

- For  $\Delta t \ll t_p$ , we get  $MSD(t) \approx 4D_{st}t$



# Modified Furth function

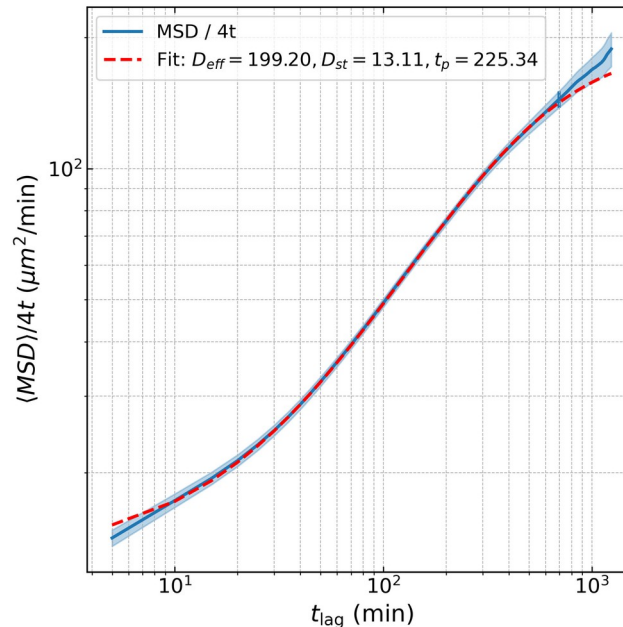
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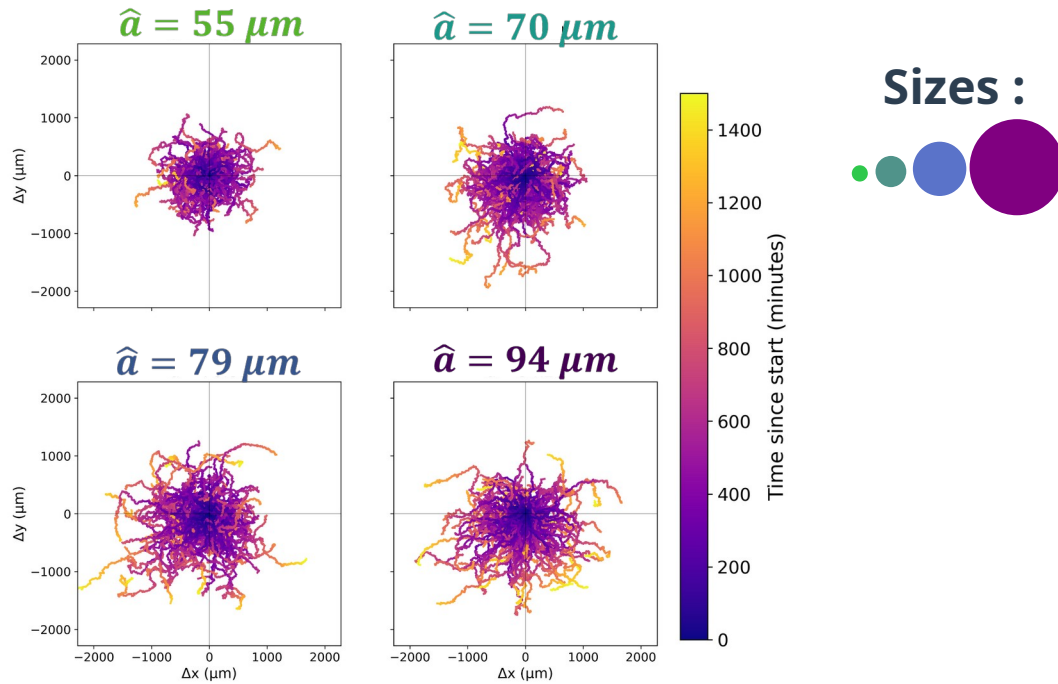
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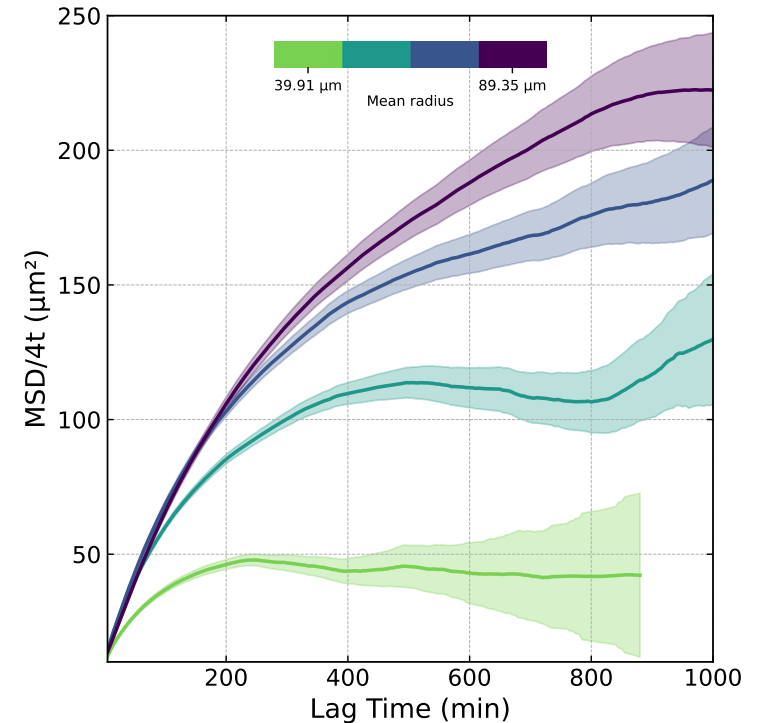


**Diffuse 10x faster  
than individual  
cells**

# MSD relative to size of aggregates

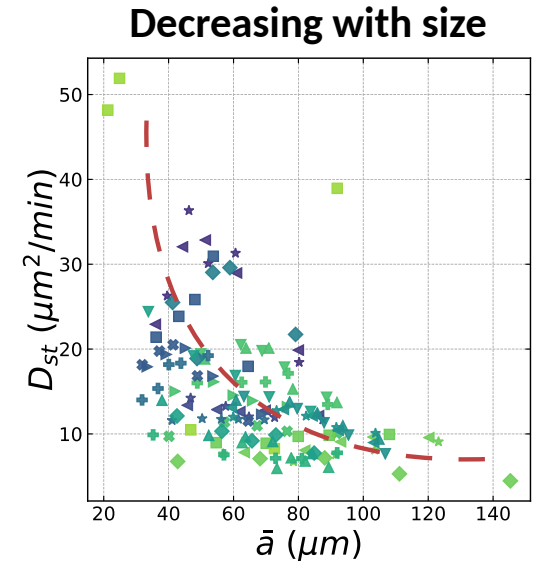
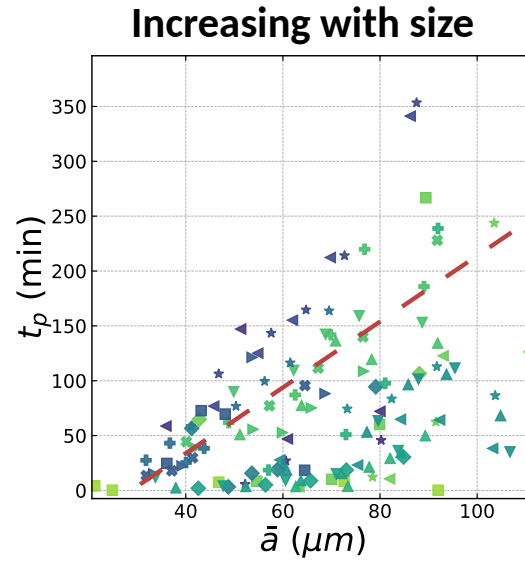
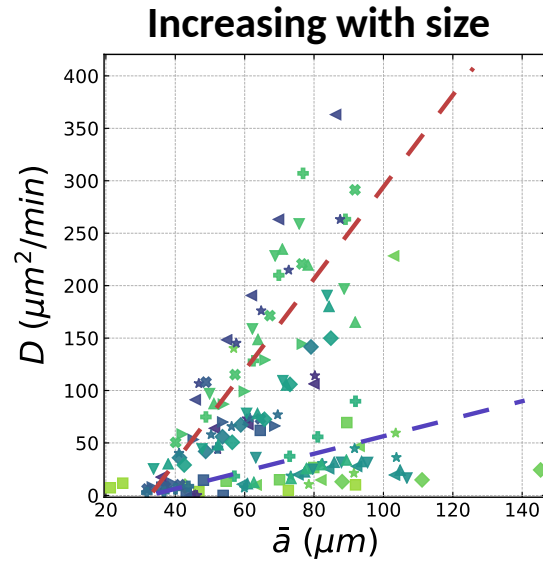
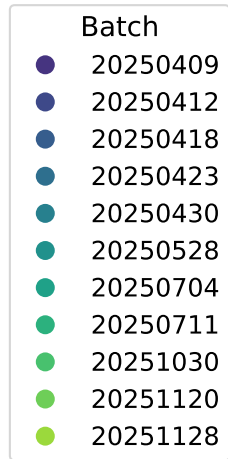


Centered trajectories of aggregate separated by size (4 bins)



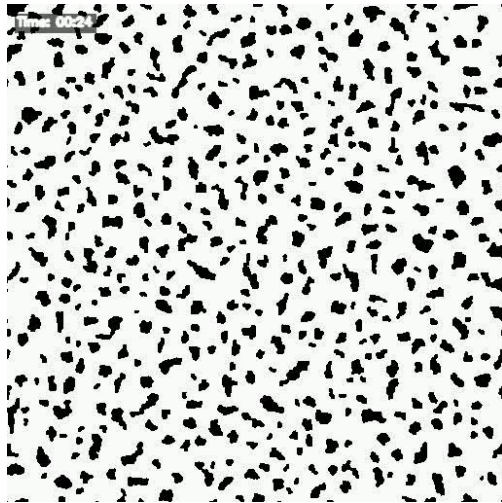
Mean Square Displacement of each bins

# Fitting parameters as a function of the size



**Diffusivity increase with size, pointing even more towards cooperativity**

# Cellular Potts Model: functional Hamiltonian

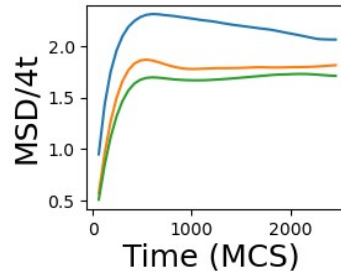


1 frame = 1 min  
1 pixel = 1 um

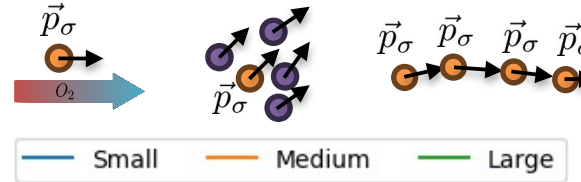
$$\arg(\vec{p}_\sigma(t+1)) = \arg\left(\underbrace{\chi \frac{\vec{\nabla} c}{c}}_{\text{Aerotaxis}} + \underbrace{\gamma \sum_{\sigma'} \vec{p}_{\sigma'}(t)}_{\text{Cooperation}} + \underbrace{\vec{p}_\sigma(t)}_{\text{Persistence}}\right) + \sqrt{\frac{2}{t_p}} \Gamma$$

**Aerotaxis**   **Cooperation**   **Persistence**

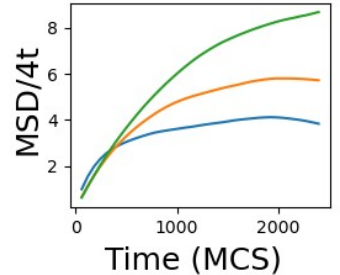
**Aerotaxis dominates**



**The smaller, the more diffusive**



**Cooperation dominates**



**The bigger, the more diffusive**

**Cooperation is necessary for this behavior**

**Thank you for you attention**